INDIANA DEPARTMENT OF TRANSPORTATION

INTER-DEPARTMENT COMMUNICATION
*Standards Section **C** Room N642*

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DESIGN MEMORANDUM No. 00-17
TECHNICAL ADVISORY

TO: **All Design, Operations, and District Personnel, and Consultants**

FROM: ***/s/ Anthony L. Uremovich***
Anthony L. Uremovich
Acting Design Policy Engineer
Contracts & Construction Division

SUBJECT: **Design Guidelines for Three-Sided Drainage Structures**

SUPERSEDES: **Design Memorandum 00-11 Technical Advisory Text (Recurring Special Provisions Attachment Still In Effect)**

EFFECTIVE: **January 17, 2001, Letting**

Introduction

These guidelines should be used for all three-sided drainage structures on both INDOT projects and federally funded LPA projects. Recurring special provision 714-R-282 has been revised and renumbered to 723-R-282 to accompany these guidelines. Recurring special provision 723-R-282f has been developed for use on those projects where the arch structure is not allowed as an option. The revised recurring special provision will be included in the September 1, 2001 update to the recurring special provisions.

Structure Sizing and Selection

If the project is on a state-maintained route and the structure qualifies as a bridge or a stand-alone "small structure replacement", the INDOT Hydraulics Unit will furnish the required minimum size for both the flat-topped and the arch structure in the hydraulic recommendations letter. The designer will choose the most appropriate alternate for the structure layout scheme shown on the plans and reference, by note, the other alternate. On projects for which the INDOT Hydraulics Unit has not prepared a hydraulic recommendation, the designer will determine the hydraulic size for both alternates.

The hydraulic recommendations will include the Q100 elevation, the assumed flow line elevation, the required span and the required waterway opening for both structure alternates. The designer will select the rise of the structure for both alternates. The minimum desirable freeboard requirement will be 0.3 m (1 ft) for both an arch structure and a flat-topped structure with the low structure elevation determined at the structure centerline for both alternates. If the designer elects to use a freeboard less than that specified in the hydraulic recommendations letter, he or she should obtain the concurrence of the Hydraulics Unit Supervisor. Generally, the flat-topped structure will be the only acceptable alternate if the freeboard is less than 0.3 m (1 ft).

Where the required structure span exceeds 9.15 m (30 ft), the INDOT Hydraulics Unit will also provide the required waterway opening for a spill-through bridge. The designer will size an appropriate bridge and perform an economic comparison between the bridge and the three-sided structure options.

The following metrication of english span dimensions should be used for designating three-sided structures on the plans and on the Schedule of Pay Items. The plans should show the structure size in meters (feet) and the Schedule of Pay Items should show the structure size in millimeters (in.). The dimension in meters should be shown to two decimal places.

Spans

English Size (ft)	Metric Size (mm)	English Size (ft)	Metric Size (mm)
12	3660	24	7310
13	3960	25	7620
14	4260	26	7920
15	4570	27	8230
16	4870	28	8530
17	5180	29	8840
18	5480	30	9140
19	5790	32	9750
20	6100	34	10 360
21	6400	36	10 970
22	6710	42	12 800
23	7010	48	14 630

The rise of the structure should be rounded to the nearest 100 mm (4 in.).

Segment Configuration and Skew

Skews should generally be in 5° intervals, although 1° intervals are permissible where necessary.

It is not necessary for the designer to determine the exact number and length of segments. The final structure length and segment configuration will be determined by the fabricator and may deviate from that implied by the plans. However, a minimum horizontal clearance of 1.8 m (6’-0”) must exist between the front face of guardrail and the outside face of the structure headwall where the drainage structure end is within the clear zone.

Square segments are generally more economical even if the structure is skewed. Laying out the structure with square segments will result in the greatest right-of-way requirement and thus allow ample space for any potential redesign by the contractor to another segment configuration.

For structures with skews less than 15°, structure segments may be laid out square or skewed, with skewed segments generally preferred for structures less than 25 m (80 ft) in length and square segments preferred for longer structures. However, skewed segments have a greater structural span. Skews greater than 15° require special analysis per AASHTO Standard Specifications for Highway Bridges Section 17.8.5.3. Skewed segments and the special analysis both contribute to higher structure cost.

The preferred layout scheme for arch structures with skews greater than 15° should assume square segments with a sloping top of headwall to yield the shortest possible wingwalls. For structures with skews greater than 15°, structure segments should be laid out square. If hydraulic conditions dictate the use of a flat-topped structure only, the segments may be laid out skewed if the structure is relatively short.

According to industry publications, a significant number of flat-topped structures are built with skewed segments, i.e., segments shaped like parallelograms. However, several INDOT structures have been redesigned to use only square segments. Where a flat-topped structure is laid out with ends parallel to the roadway, skewed segments are implied by the designer.

Where an arch structure is laid out with skewed ends (headwalls parallel to the roadway), the skew will be developed within the end segments by varying the lengths of the legs as measured along the centerline of the structure. Generally, the maximum attainable skew is controlled by the difference between the full segment leg length as recommended by the arch structure fabricator and a minimum leg length of 0.6 m (2 ft).

If the roadway above the structure is to be constructed in two phases, the designer should propose a segment skew configuration compatible with the anticipated construction line between construction phases. Therefore, if the structure length is 25 m (80 ft) or greater, a unique special provision should be included to require the contractor to design and detail special segments or cast-in-place construction required to conform to the construction line between phases. These details should be carefully reviewed by the designer when shop drawings are submitted.

Plan Requirements for Structure Layout and Detailing

The designer should select the most appropriate structure alternate for the structure layout scheme and show that alternate on the plans. The designer should use the span and rise for this alternate as a reference for the information required on the Title Sheet. The structure type to be shown on the Title, Layout, and General Plan sheets shall be Precast Reinforced Concrete Three-Sided Structure.

The General Plan should include a note or a detail indicating that an alternate structure type with a ____ m (_____ ft) span and _____ m (_____ ft) rise may be substituted for the structure indicated in the layout scheme. Where a flat-topped structure is the only option permitted, the note should state that a three-sided arch structure will not be permitted at this location.

The designer should provide the elevations on the General Plan or other detail sheet as follows:

Q100,
flow line, at both structure ends and the roadway centerline
the low structure at the centerline of the structure,
the tops of headwalls, and
the tops of wingwalls.

The assumed elevations of the top of the footing and the base of the structure leg should also be given. For structure layout purposes, assume a 0.6 m (2 ft) footing thickness with the base of the structure leg seated 50 mm (2 in.) below the top of the footing elevation. With the bottom of the footing placed at the standard depth of 1.2 m (4 ft) below the flow line elevation, the base of the structure leg should therefore be shown as 0.65 m (2'-2") below the flow line. Exceptions to the 1.2 m (4 ft) depth will occur where the anticipated footing thickness is known to exceed 0.6 m (2 ft), where the footing must extend to rock, or where poor soil conditions dictate that the footing be deeper.

The footing should be kept level whenever possible. If the stream grade prohibits a level footing, the wingwall footings must be laid out to be constructed on the same plane as the structure footings.

The designer should indicate the structure length and the flare angle, and the length and height of wingwalls. For structures that are skewed, the wingwall geometrics should be determined for each individual wing. The side slope used to determine the wing length should be clearly shown on the plans.

The pay length for skewed structures should always be measured along the skew at the centerline of the structure.

Generally, structures should extend to a point where the headwall height can be kept to a minimum, preferably 0.3 m (1 ft). All three-sided structures should have headwalls with standard-length-post guardrail protection provided unless the structure cover does not allow it. Where structure cover does not allow a standard headwall and standard-length-post guardrail installation, the designer should specify on the plans one of the options shown in Recurring Plan Details 601-R-386d, pages 9, 10, or 11 for installing guardrail over drainage structures with shallow cover. For projects to be let in or after September 2001, Standard Drawings 601-NWGA-02, -03, or –04 should be called for, as they will have replaced the recurring plan details. The designer must ensure that a minimum of 1.8 m (6'-0") of clearance exists horizontally between the face of guardrail and the outside face of the structure headwall.

For shallow cover of less than 500 mm (1'-8") and a structure width of greater than 7400 mm (24'-3"), the designer may elect to use a concrete barrier railing or type CF-1 bridge railing mounted on the structure headwall. Such railing should be shown on the plans with cast-in-place concrete and reinforcing steel detailed.

If the necessary height of the structure leg exceeds the commonly available leg lengths, the designer should show the required pedestal height in the structure elevation view. The fabricator will provide the pedestal design and details in the shop drawings or will specify longer than standard legs on the structure segments to provide the required rise. The pedestal height must be added to the precast structure leg length shown on the plans to determine the rise specified in the pay item.

The design and details for footings or base slabs, wingwall footings, wingwalls, and headwalls will be provided by the structure manufacturer when the shop drawings are submitted. The designer who prepared the contract plans will review the design calculations and shop drawings. For federal-aid local agency projects, such documents are subject to approval by the local agency or its design consultant.

The designer should refrain from showing details on the plans such as wingwall anchor systems that suggest a proprietary product. Such details should be shown on the shop drawings.

The cost of the structure and wingwall footings will be included in the cost of the structure and the wingwall, respectively. Headwalls and foundation excavation will also be included in the cost of the structure.

Foundations

The allowable soil bearing pressure should be shown on the plans. If the footing is on piling, the ultimate pile bearing load should be shown.

A table should be included on the plans listing the soil parameters for wingwall design as follows:

Angle of friction between wingwall footing and foundation soil (*),
Angle of internal friction of the foundation soil (N),
Ultimate cohesion of foundation soil (C),
Ultimate adhesion between foundation soil and concrete (C_A).

These soil parameters will be provided in the geotechnical report for the three-sided structure. If the geotechnical report is lacking this information, it should be requested from the INDOT Geotechnical Section.

Where a pile footing is required, the designer should determine the type and size of pile and the required pile spacing and show this information on the plans along with any piles that are to be battered. The final design of the pile cap will be performed by the fabricator and the details will be shown on the shop drawings as is the practice for other footing types. Payment for the pile cap will be included in the cost of the structure or the wingwall. The piling will be measured in meters (linear feet) and paid for separately in accordance with 701.15. If the geotechnical report recommends piling be used, the designer should re-evaluate the structure type selection versus a spill-through bridge in light of the added expense of a pile footing.

The plans for three-sided structures should include a sheet showing the soil boring logs for the structure.

Backfill Requirements

The structure and wingwall backfill limits should be shown on the plans. The backfill limits for all three-sided structures should have a width of 0.45 m (1.5 ft) at the bottom of the footing and should extend upward at a slope rate of 1:4. The wingwall backfill should extend upward at 1:1 slope from the bottom of the wingwall footing. The structure fabricator will also be required to show the backfill limits on the shop drawings. The backfill pay limits should be based on the neat line limits shown on the plans.

Where there is less than 0.3 m (1 ft) of cover between the structure and the proposed pavement structure, the structure shall be backfilled with flowable mortar. If an arch structure is specified, the flowable mortar backfill should extend upward to the elevation of the outside crest of the arch. This elevation shall be designated as the fill line for flowable mortar. Compacted aggregate should be used between the flowable mortar and the underside of the proposed pavement structure. The pavement design engineer should be consulted for the minimum pavement thickness to use above the structure.

Riprap and geotextile should be used on the stream banks adjacent to the wings to stabilize andprotect the B borrow for structure backfill.

Scour Considerations

The standard footing depth of 1.2 m (4.0 ft) below the flow line and the riprap protection as shown in Standard Drawings 714-CCSP-01 through 714-CCSP-03 suffice for scour protection in most routine installations.

Where the allowable soil bearing pressure is extremely low or when the stream velocity exceeds 3.0 m/s (10 ft/s) the designer should provide a concrete base slab instead of a conventional strip footing. Details of the base slab method of scour protection are shown on Standard Drawings 714-CCSP-04 and 714-CCSP-05. For borderline cases, the designer should study the cost effectiveness of providing a base slab versus providing a strip footing with riprap scour protection. The input of district construction should be requested at the preliminary field check if the costs appear to be equal.

Riprap for scour protection should be shown on the plans in accordance with Design Memorandum 98-06 Policy Change and Technical Advisory. The appropriate standard drawings should be referenced for complete riprap requirements.

Specifications/Special Provisions

Recurring special provisions 723-R-282 and 723-R-282f provide additional information and criteria which must be addressed and satisfied in the design of three-sided structures.

Schedule of Pay Items

Payment for three-sided structures will be made under the following:

Pay Item	**Pay Unit Symbol**
Structure, Precast Three-Sided, _____mm x _____mm span rise	m
(Structure, Precast Three-Sided, _____in. x _____in. span rise	LFT)
723-06660 Wingwall	m2 (SFT)

The pay item for each span and rise, of course, has its own code number. Once the designer has determined the correct pay items, he or she may get the correct pay item code numbers from the estimating software or the Contracts and Construction Division's Administrator Analyst. The specifications reference number for all of these pay items is 723.

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Attachment

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SECTION 723 -- REINFORCED CONCRETE THREE-SIDED DRAINAGE STRUCTURES

723.01 Description. This work shall consist of constructing a precast reinforced concrete three-sided arch drainage structure with headwalls and wingwalls, or a precast reinforced concrete three-sided flat-topped drainage structure with headwalls and wingwalls in accordance with 105.03 and 714. Wingwalls and headwalls may be precast or cast-in-place.

MATERIALS

723.02 Materials. The materials shall be in accordance with the following:

B Borrow for Structure Backfill	211
Flowable Mortar	213
Geotextiles	913.18
Riprap	904.04
Sealer	909.09 or 909.10

Concrete for structure sections, headwalls, pedestals, and wingwalls shall be Class A and concrete for footings and base slabs shall be Class B both in accordance with 702 except the coarse aggregate shall be Size No. 91 in accordance with 904.02.

A water-reducing admixture from the Department's list of approved Water-Reducing Admixtures may be used.

Reinforcing steel in structure sections shall be welded wire fabric, welded deformed steel wire fabric, or deformed billet steel bars in accordance with 910.01, except as noted herein. Reinforcing steel in the wingwalls, pedestals, base slabs, headwalls, and footings shall be deformed billet steel bars in accordance with 910.01. Reinforcing steel in the structure sections shall be epoxy coated.

Steel used in bolted connections of wingwalls to structure sections shall be in accordance with ASTM A 709M grade 250 (ASTM A 709 grade 36) and galvanized after fabrication in accordance with ASTM A 153M (ASTM A 153), Class A or B. Bolts shall be in accordance with ASTM A 307 and galvanized in accordance with ASTM A 153M (ASTM A 153).

CONSTRUCTION REQUIREMENTS

723.03 Shop Drawings. The Contractor shall submit, for approval, three copies of design computations and five sets of shop drawings signed by and bearing the seal of a professional engineer. A longhand example of the design methodology shall be furnished if the design calculations are in a computer printout format. The shop drawings shall include all details, dimensions, and quantities necessary to construct the structure, wingwalls, and headwalls if applicable and shall include, but not be limited to, the following information.

(a) Structure span and rise.

(b) Structure section details showing all concrete dimensions and reinforcing steel requirements.

(c) Design computations and details for pedestals, when required.

(d) Footing details showing all concrete dimensions, elevations, and reinforcing steel with bar size, length, and spacing indicated. Footing plan and section views shall be provided. The actual soil bearing pressure shall be noted on the footing detail sheets.

(e) Wingwall design computations and details showing all concrete dimensions, reinforcing steel and anchorage details. Wingwall plan, elevation, and section views shall be provided.

(f) Headwall details, showing all concrete dimensions, reinforcing steel and anchorage details. Headwall elevation and section views shall be provided.

(g) Structure backfill type and limits for the structure and wingwalls.

Structure section or wingwall fabrication shall not begin until written approval of the shop drawings and design computations have been received from the Engineer.

723.04 Design. The structure sections shall be designed for HS20-44 loading in accordance with the AASHTO Standard Specifications for Highway Bridges, except as modified herein. The minimum design concrete compressive strength for structure sections, wingwalls, and headwalls shall be 27 600 kPa (4,000 psi). Wingwalls and headwalls shall be designed based on a minimum equivalent fluid pressure of 6.3 kN/m^3 (40 lb/ft^3). If flowable mortar backfill is to be used, the Contractor shall consider the effects of hydrostatic pressure on the structure. Horizontal pressures shall be increased for sloping backfill surfaces and live load surcharge. Footings shall be designed for the allowable soil bearing shown on the plans. Wingwalls and wingwall footings shall be designed in accordance with the soil parameters shown on the plans. Wingwall footings and headwall connections shall be checked for sliding and for overturning.

Continuity shall be established between the structure footing and the wingwall footing.

1. Placement of Reinforcement. For arch structure sections, the concrete cover over the outside circumferential reinforcement shall be a minimum of 50 mm (2 in.). The cover over the inside circumferential reinforcement shall be a minimum of 40 mm (1.5 in.). The clear distance of the end circumferential reinforcement shall not be less than 25 mm (1 in.) nor more than 50 mm (2 in.) from the ends of the structure section. The ends of the longitudinal distribution reinforcement shall be not more than 75 mm (3 in.) from the ends of the structure section.

For flat-topped structure sections, the cover dimension over the top mat of reinforcement shall be a minimum of 50 mm (2 in.). The cover over the lower mat of reinforcement in the structure top shall be a minimum of 40 mm (1.5 in.). The clear distance of the end circumferential reinforcement shall not be less than 25 mm (1 in.) nor more than 50 mm (2 in.) from the ends of the structure section. The ends of the longitudinal distribution reinforcement shall not be more than 50 mm (2 in.) from the ends of the structure section.

Cover for wingwall, pedestal, and headwall reinforcement shall be a minimum of 50 mm (2 in.). Cover for footing and base slab reinforcement shall be 75 mm (3 in.) for the top and sides and 100 mm (4 in.) for the bottom.

2. Splicing and Spacing of Reinforcing Steel. Reinforcing steel splicing and spacing requirements shall be in accordance with the AASHTO Standard Specifications for Highway Bridges, except as noted herein. Tension splices in circumferential reinforcement shall be made by lapping. Deformed billet steel bars used for longitudinal distribution reinforcement shall have a center to center spacing not to exceed 300 mm (12 in.) in flat-topped structure sections or 400 mm (16 in.)in arch structure sections.

The maximum spacing for wingwall reinforcing steel shall be 450 mm (18 in.) for horizontal bars and 300 mm (12 in.) for vertical bars.

Exterior corner reinforcement for flat-topped structure sections shall be fully developed beyond the point where it is no longer required to resist flexure in accordance with the AASHTO Standard Specifications for Highway Bridges.

723.05 Manufacture. Handling devices or holes will be permitted in each structure or wingwall section. However, not more than four holes shall be cast or drilled in each section. Cast holes shall be tapered.

The section ends shall be of such design and shall be so formed that when the structure sections are erected, they shall make a continuous line of structure with a smooth interior free of irregularities.

The structure sections and wingwalls shall be free of fractures. The ends of the structure sections shall be normal to the walls and centerline, except where beveled ends are specified. The surface of the structure section shall be a smooth steel form or troweled surface. Trapped air pockets causing surface defects shall be considered as part of a smooth steel form finish.

Wingwalls shall be given a Class 2 finish in accordance with 702.21.

The structure units shall not be stored in an upright position until the designated handling and storage compressive strength, as shown on the shop drawings, has been achieved.

723.06 Marking. Each structure section and wingwall shall be clearly marked with waterproof paint. The following information shall be shown on the inside face of each wingwall and on a vertical leg of each structure section.

1. structure span and rise (structure sections only)
2. date of manufacture
3. name or trademark of the manufacturer
4. design earth cover

723.07 Testing.

1. Type of Test Specimen Concrete compressive strength shall be determined from compression tests made on cylinders or cores. For cylinder testing, a minimum of four cylinders shall be taken during each production run. For core testing, one core shall be cut from a structure section selected at random from each group of 15 structure sections or less of a particular size and production run. One core shall be cut from each group of four or fewer wingwalls. For each continuous production run, each group of 15 structure sections of a single size or fraction thereof or four wingwalls shall be considered separately for the purpose of testing and acceptance. A production run shall be considered continuous if not interrupted for more than three consecutive days.

2. Compression Testing. Cylinders shall be made and tested in accordance with ASTM C 39. Cores shall be obtained and tested for compressive strength in accordance with ASTM C 497M (ASTM C 497).

3. Acceptability of Core Tests. The compressive strength of the concrete in each group of sections as defined above will be acceptable when the core test strength is equal to or greater than the design concrete strength. The random selection and testing of the cores taken by the manufacturer will be done by the Department.

If the compressive strength of the core tested is less than the design concrete strength, the structure section or wingwall from which that core was taken may be recored. If the compressive strength of the recore is equal to or greater than the design concrete strength, the compressive strength of the concrete in that group of sections will be acceptable.

If the compressive strength of a recore is less than the design concrete strength, the structure section or wingwall from which that core was taken will be rejected. Two structure sections or wingwalls from the remainder of the group shall be selected at random. One core shall be taken from each. If the compressive strength of both cores is equal to or greater than the design concrete strength, the remainder of the structure sections or wingwalls in that group will be acceptable. If the compressive strength of either of the two cores tested is less than the design concrete strength, the remainder of the structure sections or wingwalls in the group will be rejected. However, at the option of the manufacturer, each remaining structure section or wingwall in the remainder of the group may be cored and accepted individually. The sections which have cores with less than the design concrete strength will be rejected.

4. Plugging Core Holes. The core holes shall be plugged and cured by the manufacturer in such a manner that the structure will meet all the test requirements of these specifications. Structure sections or wingwalls repaired accordingly will be considered satisfactory for use.

5. Test Equipment. The manufacturer shall furnish all facilities, equipment, and personnel necessary to conduct the required testing.

723.08 Rejection. Structure sections or wingwalls will also be rejected due to the following conditions.

1. fractures or cracks pass through the wall, except for a single end crack which does not exceed one half the thickness of the wall;

2. defects which indicate proportioning, mixing, or molding which are not in accordance with this specification;

3. honeycombed or open texture; or

4. damaged section ends, where such damage prevents making a satisfactory joint

723.09 Repairs. Structure sections or wingwalls may be repaired, if necessary, due to imperfections in manufacture, handling damage, or construction. Repairs will be acceptable if it is determined that the repairs are sound, properly finished and cured, and if the repaired structure section or wingwall is in accordance with the requirements herein.

723.10 Trench Compaction. The soils in the bottom of the excavation shall be compacted to 95% of the maximum dry density. If 95% of the maximum dry density cannot be obtained in the bottom of the excavation or in other areas, the Materials and Tests Division's Geotechnical Section shall be contacted for additional recommendations. If during construction, soft soils are encountered at depths that make removal impractical, the Materials and Tests Division's Geotechnical Section shall be contacted for additional recommendations.

723.11 Footings. Footings may be cast-in-place or precast. When a precast footing is utilized, a 100 mm (4 in.) layer of compacted aggregate No. 53 in accordance with 303 shall be placed under the full width of the footing. All footings shall be given a smooth float finish. The footing concrete shall reach a compressive strength of 13 800 kPa (2,000 psi) before placement of the structure sections or wingwalls. The surface shall not vary more than 6 mm in 3 m (**3** in. in 10 ft) when tested with 3 m (10 ft) straightedge.

723.12 Pedestals. When a reinforced concrete pedestal is required between the base of the structure leg and the top of the footing, the Contractor has the option of providing a structure with longer legs or of constructing the pedestals.

723.13 Placement of Structure Sections and Wingwalls. The structure sections and wingwalls shall be set on masonite or steel shims. A minimum gap of 13 mm (0.5 in.) shall be provided between the footing and the bottom of each section or wingwall. The gap shall be filled with a mortar in accordance with 707.09.

723.14 Sealing. Sealer shall be applied on the top surface of the structure section. Such sealer shall extend 1.5 m (5 ft) vertically down each vertical leg. Sealer material shall not be placed in keyway joints, if present. The sealer shall be provided for the full length of the structure. Surface preparation and application procedures shall be as recommended by the sealer manufacturer.

723.15 Joints. Joints between structure sections for arch structures may be either butt joints or keyway joints.

The sections for flat-topped structures shall be produced with a minimum 100 mm (4 in.) deep by 40 mm (1.5 in.) wide keyway joint. Mortar in accordance with 707.09 shall be placed in the keyway joint.

All butt joints between structure sections shall be covered with a joint wrap in accordance with ASTM C 877M (ASTM C 877), type II. The surface shall be free of dirt before the joint material is applied. The entire joint shall be continuously covered. Joints between structure sections and wingwalls and between structure sections and headwalls shall be covered with either the same wrap used between structure sections or with geotextile in accordance with 913.19.

The joint wrap shall be kept in its proper location over the joint and care shall be taken to prevent damage during the backfilling operation.

723.16 Backfilling. Tapered or drilled holes for handling shall be filled in accordance with 907.05. Prior to backfilling the structure, all holes shall be covered with joint wrap material with a minimum width of 225 mm (9 in.).

B borrow for structure backfill shall be placed and compacted in accordance with 211.

When the level of B borrow for structure backfill reaches the top of the structure, two lifts shall be spread and hand compacted over the structure without traversing the structure with heavy equipment. Compaction with heavy equipment will not be allowed until a minimum of two lifts have been placed, hand compacted, and tested.

The B borrow for structure backfill shall be placed and compacted to the same elevation on both sides of the structure before proceeding to the next layer.

When the height of cover as shown on the plans is 300 mm (12 in.) or less, the structure shall be backfilled with flowable mortar to the top of the structure.

The operation of equipment over the structure shall be in accordance with the structure manufacturer's recommendations.

723.17 Scour Protection. If riprap is used, geotextile shall first be placed on the in-situ soil in accordance with 616.10. Riprap shall then be placed in accordance with 616. For concrete base slabs, concrete shall be placed in accordance with 702.

723.18 Method of Measurement. Structures and wingwalls will not be measured for payment. The accepted quantities for payment will be the quantities shown in the Schedule of Pay Items.

B borrow for structure backfill will be measured in accordance with 211.09. Flowable mortar will be measured in accordance with 213.06. Geotextile and riprap will be measured in accordance with 616.11.

723.19 Basis of Payment. The accepted quantities of structure will be paid for at the contract unit price per meter (linear foot) for structure, precast three-sided, of the span and rise specified. The accepted quantities of wingwalls will be paid for at the contract unit

price per square meter (square foot) for wingwalls. B borrow for structure backfill will be paid for in accordance with 211.10. Flowable mortar will be paid for in accordance with 213.07. Geotextiles and riprap will be paid for in accordance with 616.12.

Payment will be made under:

Metric Pay Item.....Metric Pay Unit Symbol
(English Pay Unit .....English Pay Unit Symbol)

Structure, Precast three-Sided,
_____ mm x _____ mm. .....m
span rise
(Structure, Precast three-Sided,
_____ in. x _____ in. .....LFT)
span rise
Wingwall.....m2 (SYS)

The cost of designing, coring, testing, pedestals or longer legs, reinforcing steel, excavation, repairs, plugging core and handling holes, mortar, sealer, and necessary incidentals shall be included in the costs of the structure.

The cost of the headwalls, the concrete base slab, the footings, and the compacted aggregate base under precast footings shall be included in the cost of the structure. The cost of the footings for wingwalls and the compacted aggregate base under the wingwall footings shall be included in the cost of the wingwall.

The quantities for payment shall remain as shown on the Schedule of Pay Items whether the Contractor installs the arch structure or the flat-topped structure.

SECTION 723 -- REINFORCED CONCRETE THREE-SIDED FLAT-TOPPED DRAINAGE STRUCTURE

723.01 Description. This work shall consist of constructing a precast reinforced concrete three-sided flat-topped structure with headwalls and wingwalls in accordance with 105.03 and 714. Wingwalls and headwalls may be precast or cast-in-place.

723.02 Materials. The materials shall be in accordance with the following:

B Borrow for Structure Backfill	211
Flowable Mortar	213
Geotextiles	913.18
Riprap	904.04
Sealer	909.09 or 909.10

Concrete for structure sections, headwalls, pedestals, and wingwalls shall be Class A and concrete for footings and base slabs shall be Class B both in accordance with 702 except the coarse aggregate shall be Size No. 91 in accordance with 904.02.

A water-reducing admixture from the Department's list of approved Water-Reducing Admixtures may be used.

Reinforcing steel in structure sections shall be welded wire fabric, welded deformed steel wire fabric, or deformed billet steel bars in accordance with 910.01, except as noted herein. Reinforcing steel in the wingwalls, pedestals, base slabs, headwalls, and footings shall be deformed billet steel bars in accordance with 910.01. Reinforcing steel in the structure sections shall be epoxy coated.

Steel used in bolted connections of wingwalls to structure sections shall be in accordance with ASTM A 709M grade 250 (ASTM A 709 grade 36) and galvanized after fabrication in accordance with ASTM A 153M (ASTM A 153), Class A or B. Bolts shall be in accordance with ASTM A 307 and galvanized in accordance with ASTM A 153M (ASTM A 153).

CONSTRUCTION REQUIREMENTS

723.03 Shop Drawings. The Contractor shall submit, for approval, three copies of design computations and five sets of shop drawings signed by and bearing the seal of a professional engineer. A longhand example of the design methodology shall be furnished if the design calculations are in a computer printout format. The shop drawings shall include all details, dimensions, and quantities necessary to construct the structure, wingwalls, and headwalls if applicable and shall include, but not be limited to, the following information.

(a) Structure span and rise;

(b) Structure section details showing all concrete dimensions and reinforcing steel requirements;

(c) Design computations and details for pedestals, when required;

(d) Footing details showing all concrete dimensions, elevations, and reinforcing steel with bar size, length, and spacing

indicated. Footing plan and section views shall be provided. The actual soil bearing pressure shall be noted on the footing detail sheets.

(e) Wingwall design computations and details showing all concrete dimensions, reinforcing steel and anchorage details. Wingwall plan, elevation, and section views shall be provided.

(f) Headwall details, showing all concrete dimensions, reinforcing steel and anchorage details. Headwall elevation and section views shall be provided.

(g) Structure backfill type and limits for the structure and wingwalls.

Structure section or wingwall fabrication shall not begin until written approval of the shop drawings and design computations have been received from the Engineer.

723.04 Design. The structure sections shall be designed for HS20-44 loading in accordance with the AASHTO Standard Specifications for Highway Bridges, except as modified herein. The minimum design concrete compressive strength for structure sections, wingwalls, and headwalls shall be 27 600 kPa (4,000 psi). Wingwalls and headwalls shall be designed based on a minimum equivalent fluid pressure of 6.3 kN/m^3 (40 lb/ft^3). If flowable mortar backfill is to be used, the Contractor shall consider the effects of hydrostatic pressure on the structure. Horizontal pressures shall be increased for sloping backfill surfaces and live load surcharge. Footings shall be designed for the allowable soil bearing shown on the plans. Wingwalls and wingwall footings shall be designed in accordance with the soil parameters shown on the plans. Wingwall footings and headwall connections shall be checked for sliding and for overturning.

Continuity shall be established between the structure footing and the wingwall footing.

1. Placement of Reinforcement. The cover dimension over the top mat of reinforcement shall be a minimum of 50 mm (2 in.). The cover over the lower mat of reinforcement in the structure top shall be a minimum of 40 mm (1.5 in.). The clear distance of the end circumferential reinforcement shall not be less than 25 mm (1 in.) nor more than 50 mm (2 in.) from the ends of the structure section. The ends of the longitudinal distribution reinforcement shall not be more than 50 mm (2 in.) from the ends of the structure section.

Cover for wingwall, pedestal, and headwall reinforcement shall be a minimum of 50 mm (2 in.). Cover for footing and base slab reinforcement shall be 75 mm (3 in.) for the top and sides and 100 mm (4 in.) for the bottom.

2. Splicing and Spacing of Reinforcing Steel. Reinforcing steel splicing and spacing requirements shall be in accordance with the AASHTO Standard Specifications for Highway Bridges, except as noted herein. Tension splices in circumferential reinforcement shall be made by lapping. Deformed billet steel bars used for longitudinal distribution reinforcement shall have a center to center spacing not to exceed 300 mm (12 in.) in flat-topped structure sections.

The maximum spacing for wingwall reinforcing steel shall be 450 mm (18 in.) for horizontal bars and 300 mm (12 in.) for vertical bars.

Exterior corner reinforcement shall be fully developed beyond the point where it is no longer required to resist flexure in accordance with the AASHTO Standard Specifications for Highway Bridges.

723.05 Manufacture. Handling devices or holes will be permitted in each structure or wingwall section. However, not more than four holes shall be cast or drilled in each section. Cast holes shall be tapered.

The section ends shall be of such design and shall be so formed that when the structure sections are erected, they shall make a continuous line of structure with a smooth interior free of irregularities.

The structure sections and wingwalls shall be free of fractures. The ends of the structure sections shall be normal to the walls and centerline, except where beveled ends are specified. The surface of the structure section shall be a smooth steel form or troweled surface. Trapped air pockets causing surface defects shall be considered as part of a smooth steel form finish.

Wingwalls shall be given a Class 2 finish in accordance with 702.21.

The structure units shall not be stored in an upright position until the designated handling and storage compressive strength, as shown on the shop drawings, has been achieved.

723.06 Marking. Each structure section and wingwall shall be clearly marked with waterproof paint. The following information shall be shown on the inside face of each wingwall and on a vertical leg of each structure section.

1. structure span and rise (structure sections only)

2. date of manufacture

3. name or trademark of the manufacturer

4. design earth cover

723.07 Testing.

1. Type of Test Specimen Concrete compressive strength shall be determined from compression tests made on cylinders or cores. For cylinder testing, a minimum of four cylinders shall be taken during each production run. For core testing, one core shall be cut from a structure section selected at random from each group of 15 structure sections or less of a particular size and production run. One core shall be cut from each group of four or fewer wingwalls. For each continuous production run, each group of 15 structure sections of a single size or fraction thereof or four wingwalls shall be considered separately for the purpose of testing and acceptance. A production run shall be considered continuous if not interrupted for more than three consecutive days.

2. Compression Testing. Cylinders shall be made and tested in accordance with ASTM C 39. Cores shall be obtained and tested for compressive strength in accordance with ASTM C 497M (ASTM C 497).

3. Acceptability of Core Tests. The compressive strength of the concrete in each group of sections as defined above will be acceptable when the core test strength is equal to or greater than the design concrete strength. The random selection and testing of the cores taken by the manufacturer will be done by the Department.

If the compressive strength of the core tested is less than the design concrete strength, the structure section or wingwall from which that core was taken may be recored. If the compressive strength of the recore is equal to or greater than the design concrete strength, the compressive strength of the concrete in that group of sections will be acceptable.

If the compressive strength of a recore is less than the design concrete strength, the structure section or wingwall from which that core was taken will be rejected. Two structure sections or wingwalls from the remainder of the group shall be selected at random. One core shall be taken from each. If the compressive strength of both cores is equal to or greater than the design concrete strength, the remainder of the structure sections or wingwalls in that group will be acceptable. If the compressive strength of either of the two cores tested is less than the design concrete strength, the remainder of the structure sections or wingwalls in the group will be rejected. However, at the option of the manufacturer, each remaining structure section or wingwall in the remainder of the group may be cored and accepted individually. The sections which have cores with less than the design concrete strength will be rejected.

4. Plugging Core Holes. The core holes shall be plugged and cured by the manufacturer in such a manner that the structure will meet all the test requirements of these specifications. Structure sections or wingwalls repaired accordingly will be considered satisfactory for use.

5. Test Equipment. The manufacturer shall furnish all facilities, equipment, and personnel necessary to conduct the required testing.

723.08 Rejection. Structure sections or wingwalls will also be rejected due to the following conditions.

1. fractures or cracks pass through the wall, except for a single end crack which does not exceed one half the thickness of the wall;

2. defects which indicate proportioning, mixing, or molding which are not in accordance with this specification;

3. honeycombed or open texture; or

4. damaged section ends, where such damage prevents making a satisfactory joint

723.09 Repairs. Structure sections or wingwalls may be repaired, if necessary, due to imperfections in manufacture, handling damage, or

construction. Repairs will be acceptable if it is determined that the repairs are sound, properly finished and cured, and if the repaired structure section or wingwall is in accordance with the requirements herein.

723.10 Trench Compaction. The soils in the bottom of the excavation shall be compacted to 95% of the maximum dry density. If 95% of the maximum dry density cannot be obtained in the bottom of the excavation or in other areas, the Materials and Tests Division's Geotechnical Section shall be contacted for additional recommendations. If during construction, soft soils are encountered at depths that make removal impractical, the Materials and Tests Division's Geotechnical Section shall be contacted for additional recommendations.

723.11 Footings. Footings may be cast-in-place or precast. When a precast footing is utilized, a 100 mm (4 in.) layer of compacted aggregate No. 53 in accordance with 303 shall be placed under the full width of the footing. All footings shall be given a smooth float finish. The footing concrete shall reach a compressive strength of 13 800 kPa (2,000 psi) before placement of the structure sections or wingwalls. The surface shall not vary more than 6 mm in 3 m (**3** in. in 10 ft) when tested with 3 m (10 ft) straightedge.

723.12 Pedestals. When a reinforced concrete pedestal is required between the base of the structure leg and the top of the footing, the Contractor has the option of providing a structure with longer legs or of constructing the pedestals.

723.13 Placement of Structure Sections and Wingwalls. The structure sections and wingwalls shall be set on masonite or steel shims. A minimum gap of 13 mm (0.5 in.) shall be provided between the footing and the bottom of each section or wingwall. The gap shall be filled with a mortar in accordance with 707.09.

723.14 Sealing. Sealer shall be applied on the top surface of the structure section. Such sealer shall extend 1.5 m (5 ft) vertically down each vertical leg. Sealer material shall not be placed in keyway joints, if present. The sealer shall be provided for the full length of the structure. Surface preparation and application procedures shall be as recommended by the sealer manufacturer.

723.15 Joints. The structure sections shall be produced with a minimum 100 mm (4 in.) deep by 40 mm (1.5 in.) wide keyway joint. Mortar in accordance with 707.09 shall be placed in the keyway joint.

All butt joints between structure sections shall be covered with a joint wrap in accordance with ASTM C 877M (ASTM C 877), type II. The surface shall be free of dirt before the joint material is applied. The entire joint shall be continuously covered. Joints between structure sections and wingwalls and between structure sections and headwalls shall be covered with either the same wrap used between structure sections or with geotextile in accordance with 913.19.

The joint wrap shall be kept in its proper location over the joint and care shall be taken to prevent damage during the backfilling operation.

723.16 Backfilling. Tapered or drilled holes for handling shall be

filled in accordance with 907.05. Prior to backfilling the structure, all holes shall be covered with joint wrap material with a minimum width of 225 mm (9 in.).

B borrow for structure backfill shall be placed and compacted in accordance with 211.

When the level of B borrow for structure backfill reaches the top of the structure, two lifts shall be spread and hand compacted over the structure without traversing the structure with heavy equipment. Compaction with heavy equipment will not be allowed until a minimum of two lifts have been placed, hand compacted, and tested.

The B borrow for structure backfill shall be placed and compacted to the same elevation on both sides of the structure before proceeding to the next layer.

When the height of cover as shown on the plans is 300 mm (12 in.) or less, the structure shall be backfilled with flowable mortar to the top of the structure.

The operation of equipment over the structure shall be in accordance with the structure manufacturer's recommendations.

723.17 Scour Protection. If riprap is used, geotextile shall first be placed on the in-situ soil in accordance with 616.10. Riprap shall then be placed in accordance with 616. For concrete base slabs, concrete shall be placed in accordance with 702.

723.18 Method of Measurement. Structures and wingwalls will not be measured for payment. The accepted quantities for payment will be the quantities shown in the Schedule of Pay Items.

B borrow for structure backfill will be measured in accordance with 211.09. Flowable mortar will be measured in accordance with 213.06. Geotextile and riprap will be measured in accordance with 616.11.

723.19 Basis of Payment. The accepted quantities of structure will be paid for at the contract unit price per meter (linear foot) for structure, precast three-sided, of the span and rise specified. The accepted quantities of wingwalls will be paid for at the contract unit price per square meter (square foot) for wingwalls. B borrow for structure backfill will be paid for in accordance with 211.10. Flowable mortar will be paid for in accordance with 213.07. Geotextiles and riprap will be paid for in accordance with 616.12.

Payment will be made under:

Metric Pay Item.....Metric Pay Unit Symbol
(English Pay Unit .....English Pay Unit Symbol)

Structure, Precast three-Sided,
_____ mm x _____ mm. .....m
span rise
(Structure, Precast three-Sided,
_____ in. x _____ in. .....LFT)
span rise
Wingwall.....m2 (SFT)

The cost of designing, coring, testing, pedestals or longer legs, reinforcing steel, excavation, repairs, plugging core and handling holes, mortar, sealer, and necessary incidentals shall be included in the cost of the structure.

The cost of the headwalls, the concrete base slab, the footings, and the compacted aggregate base under precast footings shall be included in the cost of the structure. The cost of the footings for wingwalls and the compacted aggregate base under the wingwall footings shall be included in the cost of the wingwall.